Thermal Resistance of Double Skin Insulated Sheet Steel Walls & Roofs

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BUILDING INSTITUTE

PREFACE

One of the objects of the CSSBI and its members is the development of standards which promote safety, performance and good practice.

This bulletin is intended to assist designers and specifiers of double skin insulated sheet steel walls and roofs by providing information on how to calculate the thermal resistance of typical assemblies.

The material presented has been prepared for the general information of the reader. While the material is believed to be technically correct and in accordance with recognized good practice at the time of publication, it should not be construed as obviating the need to secure competent advice with respect to its suitability for a given situation. Neither the Canadian Sheet Steel Building Institute nor its Members warrant or assume liability for the suitability of the material for any general or particular application.

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THERMAL RESISTANCE OF DOUBLE SKIN INSULATED SHEET STEEL WALLS & ROOFS

1. INTRODUCTION

The Canadian Sheet Steel Building Institute recently sponsored a research program investigating ways of improving the thermal resistance of insulated sheet steel wall and roof assemblies. These tests were performed by the Institute for Research in Construction of the National Research Council of Canada. The objectives of this program were two-fold:

1) to determine the actual thermal resistance of a variety of typical sheet steel wall and roof assemblies; and,
2) to formulate analytical methods of predicting the thermal resistance of various sheet steel wall and roof assemblies.

This bulletin presents the analytical methods of calculating the thermal resistance of glass fibre insulated sheet steel wall and roof assemblies. The methods are limited in their applicability to assemblies similar to those tested. Some variations in construction details are possible without compromising the validity of the calculation procedures.

2. HEAT LOSSES THROUGH WALL AND ROOF ASSEMBLIES

Heat energy travels by a combination of conduction, radiation and convection. Within the solid materials of an assembly, the mechanisms of conduction and radiation are well known. The heat losses due to convection, however, have not been quantified until now.

Convection is the movement of air in a circular flow initiated by having two adjacent surfaces at different temperatures. As the air is warmed by one surface it rises; similarly, the air adjacent to the cold surface settles as it cools. This process of warming and cooling air movements causes a convection current to build up within the cavity between the two surfaces. The CSSBI test program indicates that these convection heat losses become more significant as the thickness and slope of the insulated assembly increase and as the resulting temperature differential across the insulation increases.

For these convection currents to build up, there must be air spaces on both the warm and cold sides of the insulation. These air spaces are created by the profiled sheet steel cladding and liner sheets if the insulation does not fill the full depth of the cavity.

Since the insulation acts to create the temperature differential within the assembly, convection currents will develop in the air spaces adjacent to this insulation. Convection currents do not build up within the insulation itself due to its density and resulting resistance to air movements. However, the air will pass through the insulation at the top and bottom of the assembly thus completing the convection cycle.

Convection currents in highly insulated assemblies can be controlled by the addition of a "convection barrier". This barrier is flush with one side of the insulation and effectively separates the two air spaces thereby stopping the convective cycle. Research indicates that a convection barrier placed on the cold side of the insulation is most effective.

A convection barrier differs from an air barrier and a vapour barrier in its basic requirements. A convection barrier must resist the convective movement of air; however, it must not act as a vapour barrier and impede the movement of vapour (particularly since it is installed on the cold side of the insulation). It is not necessary for a convection barrier to have the same strength requirements as an air barrier. Often, however, the functions of an air barrier and a convection barrier are provided by the same material. Both Kraft paper and the product Tyvek (a registered trademark of E.I. Dupont de Nemours & Co. Inc.), which is a spun olefin material, were used in the research as convection barriers.

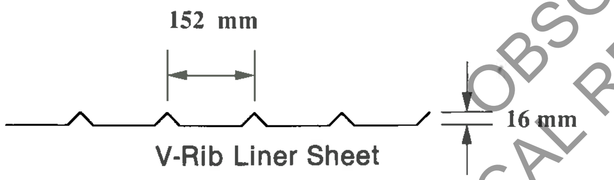
With the elimination of convection heat losses, the calculation of the thermal resistance of a sheet steel wall or roof assembly is reduced to the determination of the conductive heat flow through the various components. This procedure is relatively straight forward.

3. DESCRIPTION OF WALL & ROOF SYSTEMS TO WHICH THE THERMAL CALCULATION PROCEDURE APPLIES

3.1 **General:** The type of wall and roof assemblies which were tested and used as a basis for the thermal resistance calculation procedures are illustrated in Figure 1. Although the calculation procedures were based on these specific assemblies, certain variations in an assembly, as described below, can be made without significantly affecting the applicability of the calculation method.

3.2 **Liner Sheet:** One type of steel liner sheet was used in the wall and roof tests as illustrated below. By caulking the sidelaps, the liner was designed to act as the vapour barrier.

Since the formation of a convective heat flow is enhanced by having air spaces adjacent to the insulation (e.g. along the flutes of the corrugated sheet), a flat liner would be more effective in reducing convection. The calculation procedure proposed is assumed to be valid for assemblies that have liner sheets the same as shown or flatter.



V-Rib Liner Sheet

3.3 **Convection Barrier:** The calculation procedure assumes a convection barrier on the cold side of the insulation. However, a convection barrier is not required for roofs of less than 10° slope. To be effective, the convection barrier must have all joints and edges sealed. Two types of convection barriers were used in the tests, Kraft paper and Tyvek.

3.4 **Exterior Cladding:** With the introduction of a convection barrier into the assembly, air within the space between the insulation and the flutes of the exterior cladding is prevented from circulating within the assembly. Consequently, the exterior cladding profile has no influence on the thermal resistance of the assembly.

3.5 **Insulation:** The wall thermal tests were done using two densities of glass fiber insulation: 17.6 kg/m^3 and 28.8 kg/m^3 in thicknesses of 152 mm and 254 mm. The roof tests used 17.6 kg/m^3 insulation in 152 mm thickness only.

When incorporating the thermal resistance of the insulation into the calculation procedure, its published value should be used.

3.6 **Subgirts and Subpurlins:** The wall testing was carried out using both plain and perforated Z girts as well as a thermal clip system. The roof testing incorporated both notched Z spacers and hat section/thermal clip sub-assemblies.

The theoretical calculation method provided in this bulletin is based on assemblies with plain Z girts. However, the basic calculation approach applies equally to walls or roofs incorporating any type of subgirt or subpurlin system, provided that the thermal conductivity of the sub-system is established by test or analysis.

3.7 **Fasteners:** Sheet metal screws were used to fasten the various components of the assembly to the supporting structure. Wall tests were conducted with only one half of the number of screws and the resulting change in thermal resistance was within the 5% range of experimental error. Therefore, varying the number of screws should not affect the thermal resistance calculations.

3.8 **Temperature Difference:** The tests were carried out at a constant warm side temperature of 21°C and cold side temperatures of -7°C ($\Delta T = 28°C$) and -35°C ($\Delta T = 56°C$). The choice of a temperature difference will affect the calculation of the thermal resistance of the assembly since the insulating properties of some materials vary with temperature.

3.9 **Surface Temperature:** The calculation procedure does not specifically include a calculation of the temperature on the interior surface. The research on a 152 mm wall with a cold side temperature of -35°C shows a surface temperature of not less than 10°C anywhere on the face of the interior liner. This interior surface temperature would not give rise to condensation problems in most interior environments.

4. CALCULATION PROCEDURES

4.1 **Walls:** The analytical procedure for determining the thermal resistance of an insulated sheet steel wall assembly with thermal bridges is as follows:

1) Determine the RSI value of insulation for a given wall thickness and mean insulation temperature.

2) To obtain the RSI value of an unbridged wall, R_{wu}, multiply the RSI value of the insulation by a factor which depends on the temperature difference and the wall thickness.

3) Divide the obtained R_{wu}, unbridged wall resistance, by the area of the wall, A_w, to obtain Z_{wu}.

4) Calculate Z_{girt} using the equation $Z_{girt} = \ell / kA_{girt}$ where A_{girt} is the cross sectional area of the girt perpendicular to the direction of heat flow, ℓ is the length of the thermal path, and k is the thermal conductivity of the steel in the girt.

5) Determine an appropriate interface resistance value, Z_{ext}.

6) The bridged wall resistance Z_{br} is obtained by adding Z_{girt} and Z_{ext}:

$$Z_{br} = Z_{girt} + Z_{ext}$$

7) If there are "n" different bridges in the wall, obtain Z_{br} as follows:

$$Z_{br} = \frac{1}{\frac{1}{Z_{br1}} + \frac{1}{Z_{br2}} + \ldots \frac{1}{Z_{brn}}}$$

8) The total thermal resistance of a bridged wall, Z_w, excluding the air film resistance, is:

$$Z_w = \frac{1}{\frac{1}{Z_{wu}} + \frac{1}{Z_{br}}}$$

9) The total thermal resistance, R_w, of a bridged wall per unit area, including the inside air film resistance, f_i, and outside air film resistance, f_o, is:

$$R_w = (Z_w \times A_w) + f_i + f_o$$

4.2 **Roofs:** The analytical procedure for determining the thermal resistance of an insulated sheet steel roof assembly with thermal bridges is as follows:

1) Determine the unit unbridged roof resistance, R_{ru}, using factors dependent on temperature difference, insulation, inclination and whether or not there is a convection barrier.

2) Determine the unbridged resistance, Z_{ru}, by dividing R_{ru} by the total roof area A_r:

$$Z_{ru} = \frac{R_{ru}}{A_r}$$

3) Calculate the component resistance of each component of a thermal bridge, Z_{icomp}, and sum for the total number of components such as purlins, hat sections, clips, etc.:

$$Z_{comp} = \Sigma Z_{icomp}$$

4) Determine the resistance of one complete thermal bridge Z_{br} by multiplying by an average ratio factor of 1.32:

$$Z_{br} = 1.32 \times Z_{comp}$$

5) Find the total resistance of "n" identical thermal bridges by dividing Z_{br} by n:

$$Z_{brtot} = \frac{Z_{br}}{n}$$

6) Sum the resistance to give the total roof resistance Z_r:

$$Z_r = \frac{1}{\frac{1}{Z_{ru}} + \frac{0.89}{Z_{brtot}}}$$

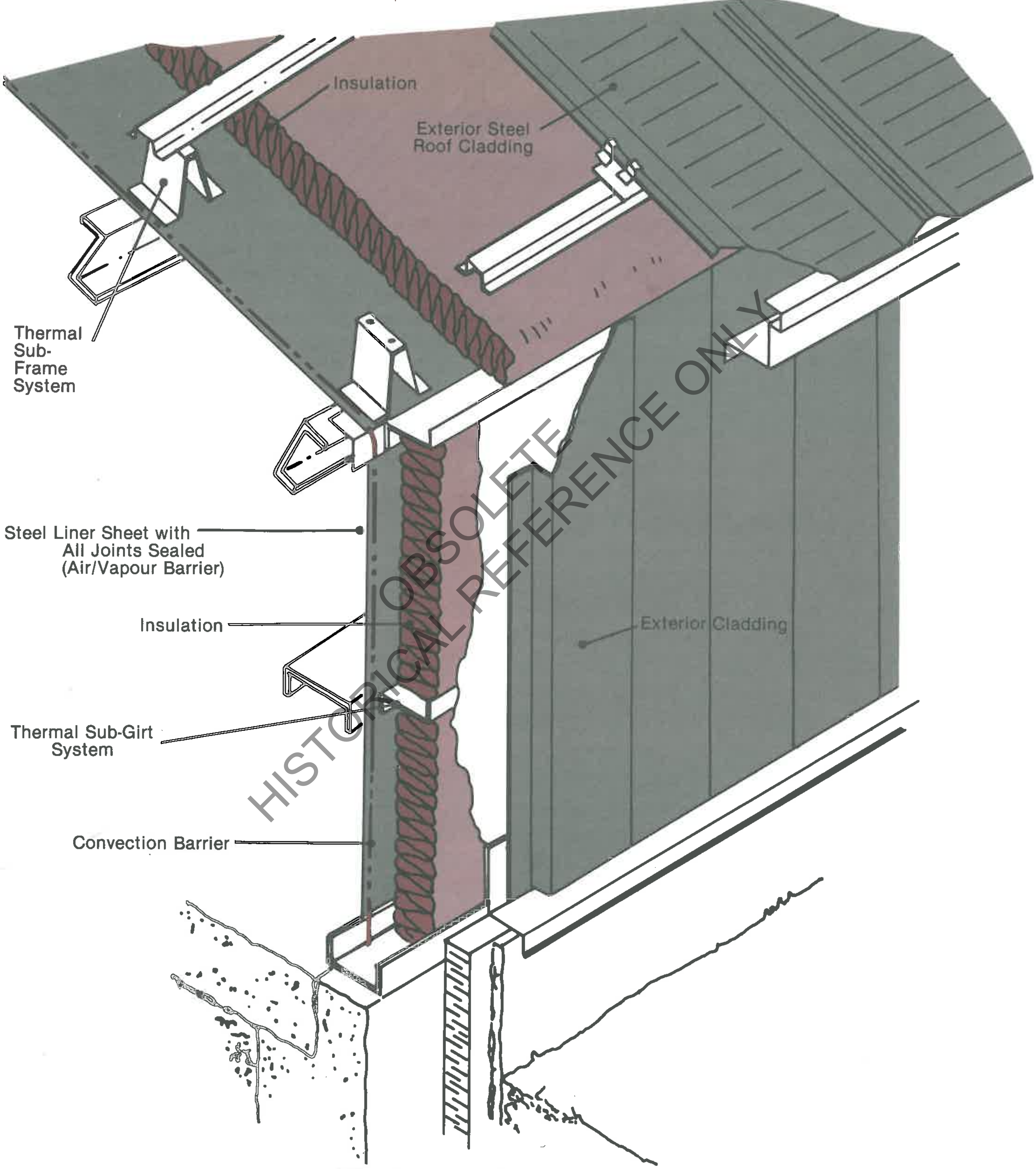
7) The total thermal resistance, R_r, of a bridged roof, including the inside air film resistance, f_i, and outside air film resistance, f_o, is:

$$R_r = (Z_r \times A_r) + f_i + f_o$$

***Note:** For exact calculations or inquiries concerning the calculations, please contact a CSSBI member company.*

FIGURE 1

SIMPLIFIED EXAMPLE OF A DOUBLE SKIN SHEET STEEL WALL & ROOF ASSEMBLY



* Details may vary by manufacturer

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The institute provides information regarding the standards of design, fabrication and erection, and offers technical assistance in the use of cold formed and pre-engineered steel products. The CSSBI also represents its members in technical matters connected with government, and provides liaison with organizations such as Canadian Standards Association and National Research Council.

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305-201 Consumers Road, Willowdale, Ontario M2J 4G8 (416) 493-8780

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